JOURNAL OF THE
WORLD AQUACULTURE SOCIETY

Volume 35, No. 4
December 2004

Diel Foraging Behavior of American White Pelicans *Pelecanus erythrorhynchos* on Experimental Aquaculture Ponds

SCOTT J. WERNER[1]

United States Department of Agriculture, Animal and Plant Health Inspection Service, Wildlife Services, National Wildlife Research Center, Mississippi Field Station, P.O. Drawer 6099, Mississippi State University, Mississippi, 39762, USA

Abstract—Videography and night vision equipment were used to observe the diurnal and nocturnal activities of American white pelicans *Pelecanus erythrorhynchos* ($N = 6$) foraging on three experimental (0.04 ha) channel catfish (*Ictalurus punctatus*) aquaculture ponds in March 2001. Captive pelicans spent most time foraging per hour from 1700 through 2300 h (CST). No foraging was observed from 0700 through 0800 h. Fish captures per hour were greatest from 1700 through 1900 h. On average, captive pelicans ($N = 5$) consumed 1.0 ± 0.2 kg of catfish per bird per day during the 10-d foraging trial. This consumption corresponds with an average intake of over 60,000 kJ of energy per bird during the trial. Relative to morning hours, the average number of bill dips per min was greater during afternoon foraging bouts. Fish captures per bill dip, however, did not differ among trial hours. Thus, pelicans were observed to increase foraging effort subsequent to 1500 h and thereby consumed 224 to 532 catfish (average = 313 ± 74 fish; $N = 4$) during the 10-d foraging trial in ponds stocked with approximately 74,000 catfish/ha.

The increased presence of American white pelicans *Pelecanus erythrorhynchos* in the southeastern United States has caused interest in the foraging ecology and related economic impacts of these birds on regional production of cultured fishes (King and Werner 2001). Since 1990, conflicts regarding pelican foraging at channel catfish *Ictalurus punctatus* aquaculture facilities in Mississippi, Arkansas, and Louisiana have been reported to the United States Department of Agriculture (King 1997). Measurements of bill and neck lengths of adult pelicans suggest that they are restricted to foraging on prey in the upper 1.25 m of the water column (Anderson 1991). Indeed, McMahon and Evans (1992) observed that most fish were captured by pelicans in water less than 1-m deep. Whereas most ponds at channel catfish aquaculture facilities are 1- to 2-m deep, pelicans are able to exploit cultured fishes throughout most aquaculture ponds (King 1997). Although the diurnal activities of American white pelicans in Mississippi and Louisiana have been investigated (King and Werner 2001), Anderson (1987) suggested that "pelicans must be doing a sizable proportion of their feeding at night" on open waters in western Nevada.

Such nocturnal foraging has been observed among American white pelicans breeding on the Great Salt Lake, Utah (Low et al. 1950); Yellowstone Lake, Wyoming (Schaller 1964); Pyramid Lake, Nevada (Anderson 1991); and Kawinaw Lake (O'Malley and Evans 1984) and Lake Winnipeg (McMahon and Evans 1992) in Manitoba, Canada. Diurnal foraging, however, may be sufficient during winter months "when energy needs would presumably be reduced" relative to the breeding season (McMahon and Evans 1992). Thus, it has been suggested that wintering American white pelicans do not feed at night (Audubon, in Palmer 1962; Evans and Knopf 1993). The objectives of this study were: 1) to evaluate the diel foraging behavior of captive pelicans on experimental catfish aquaculture ponds during late winter, and 2) to determine the abundance of catfish consumed by pelicans while controlling for other fish mortality factors (e.g., disease, poor water quality).

Materials and Methods

From 14 February to 1 March 2001, six American white pelicans were captured in western Mis-

[1]*Present address: United States Department of Agriculture, Animal and Plant Health Inspection Service, Wildlife Services, National Wildlife Research Center, 4101 LaPorte Avenue, Fort Collins, Colorado 80521, USA.*

sissippi using methods described by King et al. (1998). All pelicans were weighed to the nearest 0.1 kg (average = 6.1 kg; range = 5.7–6.5 kg) and marked with a unique leg band. This study was conducted in our 0.6-ha research aviary that contains three experimental aquaculture ponds (Glahn and Dorr 2002). Each of three birds was randomly assigned and released in an enclosed aviary that contained an experimental aquaculture pond (0.04 ha, 40–130 cm deep). The remaining three pelicans were held in individual cages (3 m x 3 m x 1.8 m high) adjacent to test ponds.

One half of each pond was excluded from pelican foraging via vertical (sub-surface) screening and horizontal netting. Since some fish mortality cannot be observed above the water surface (i.e., some fish sink), control pond halves were used to estimate fish mortality during the trial (i.e., fish mortality independent of pelican impacts). Pond halves were stocked with 1,500 channel catfish fingerlings to simulate a stocking rate of approximately 74,000 fish/ha. The vertical screening contained fish within the pond half where they were stocked. We weighed a sample of 100 catfish prior to stocking each pond half to estimate fish mass (± 1 g) and predict fish length (Carlander 1969). Limited fish availability enabled us to stock the treated (pelican-present) half of pond 2 with only 1,235 fish during the first trial. We recorded observed (i.e., floating) fish mortality on each pond daily throughout the trial. Caged pelicans were offered 1.0 to 1.5 kg of live fish/d (based upon prior daily consumption). Visual barriers were placed between cages and test ponds to minimize disturbance during the study.

The study consisted of two 10-d foraging trials. A video cassette recorder was used to document the diurnal activity of one randomly selected pelican from 0600–1200 h and 1200–1800 h (CST) during each trial day. Subsequent video analyses provided estimates of foraging time (± 1 min), fish captures, rate of bill dipping (*N* bill dips/observed pelican per min foraging), and efficiency of catfish captures (*N* catfish captures/*N* bill dips) during recorded foraging bouts. The night vision monocular and telephoto lens described by King and King (1994) were used to observe and record the foraging time (± 1 min) and fish captures of all pelicans during three nocturnal observation periods (1800–2200 h, 2200–0200 h, and 0200–0600 h). Sunrise and sunset occurred from 0551–0621 h and 1754–1811 h, respectively, during the study. Morning and afternoon water temperatures within experimental ponds ranged from 7.7–16.9 C and 7.7–19.3 C, respectively.

The beginning of a foraging bout was regarded as the first dipping of the bill in experimental ponds. The conclusion of a foraging bout was marked by a prolonged interval (≥ 1 min) between bill dips. Because several fish may be consumed by pelicans per "capture," no attempt was made to distinguish the number of fish ingested. Thus, captures were regarded as "mouthfuls" and were recorded upon pelicans raising their head above a horizontal plane in a swallowing motion (i.e., one capture per mouthful).

Subsequent to the first 10-d trial, the first group of three pelicans was removed from experimental ponds, and fish within ponds were seined and counted. Ponds were then refilled with water and catfish fingerlings (1,500 fish in each pond half). The remaining three pelicans were then randomly assigned and released within the aviary (one pelican on each of three test ponds) for the duration of the second trial. Fish mass during the first trial averaged 39–44 g/fish (predicted length = 19–19.5 cm) and 24–46 g/fish (16–20 cm long) among pond halves during the first and second trial, respectively. Erosion adjacent to the vertical screening that separated the halves of pond 1 precluded the use of fish consumption data from this pond during the second trial.

A repeated measures ANOVA (PROC Mixed) was used to analyze differences in average foraging time and average fish captures among diel observations using SAS version 8 software (SAS Institute, Inc., Cary, North Carolina, USA). The independent variables of these analyses were birds, observation periods (i.e., within, or repeated measure; midnight–0600, 0600–1200, 1200–1800, 1800–2400), and trial days. A repeated measures ANOVA was also used to analyze differences in the average rate of bill dipping and efficiency of catfish captures among diurnal observations. The independent variables of these analyses were birds, hours, and trial days. Tukey post-hoc contrasts were used to separate the means of significant ($P \leq 0.05$) ANOVA effects. Descriptive statistics (mean

± SEM) were used to characterize catfish consumption and energetic intake (Brugger 1993) during the study.

Results

The diel activities of captive American white pelicans were observed for 251 h. The average time that pelicans spent foraging per hour (Fig. 1) differed among observation periods ($F_{3,15} = 11.1$, $P < 0.001$). Mean foraging time was least from 0600–1200 h ($P < 0.05$). Foraging time was greater from 1800–2400 h than from 1200–1800 h ($P < 0.05$). Three pelicans foraged more than 30 min/h between 1800 and 2300 h. Two of these birds also foraged more than 30 min/h between 0300 and 0600 h. No foraging was observed from 0700 through 0800 h. Thus, most foraging per hour was observed within 6 h prior to midnight. Catfish captures per hour (Fig. 2) also differed among observation periods ($F_{3,15} = 5.4$, $P = 0.01$). Fish captures were greater from 1200–1800 h than from 0600–1200 h ($P < 0.05$).

Captive pelicans consumed 224 to 532 catfish fingerlings per bird (average = 313 ± 74 fish; $N = 4$) during the 10-d foraging trial in ponds stocked with approximately 74,000 catfish/ha (Table 1). This consumption corresponds with an average intake of 1.0 ± 0.2 kg of catfish per day and over 60,000 kJ of energy during the 10-d foraging trials ($N = 5$). Fish consumption within the pond half stocked with 1,235 fingerlings was approximately 34% of the fish consumption within pond halves stocked with 1,500 fingerlings. Average fish mass (per fish) within the pond stocked with 1,235 fish per pond half was, however, greater than that in other test ponds (Table 1).

The diurnal foraging behavior of captive American white pelicans ($N = 6$) was observed for 228 h. During this time, pelicans spent 1,178 min foraging (8.6%), 11,817 min loafing on

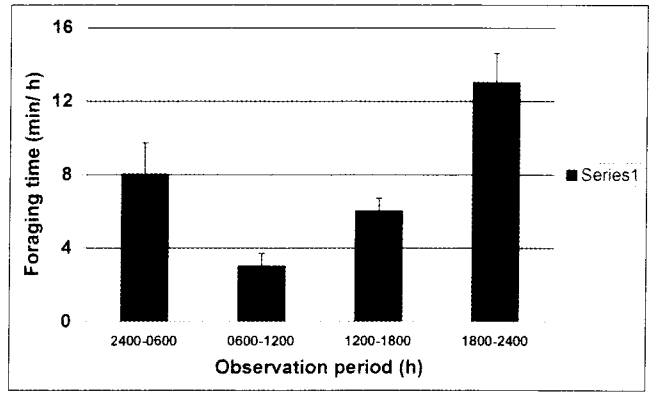

FIGURE 1. *Average (± SEM) foraging time among diel observations of captive American White Pelicans (N = 6) foraging on experimental channel catfish aquaculture ponds.*

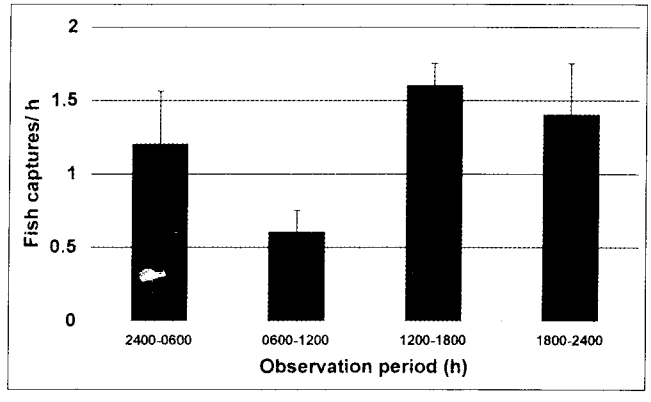

FIGURE 2. *Average (± SEM) fish captures among diel observations of captive American white pelicans (N = 6) foraging on experimental channel catfish aquaculture ponds.*

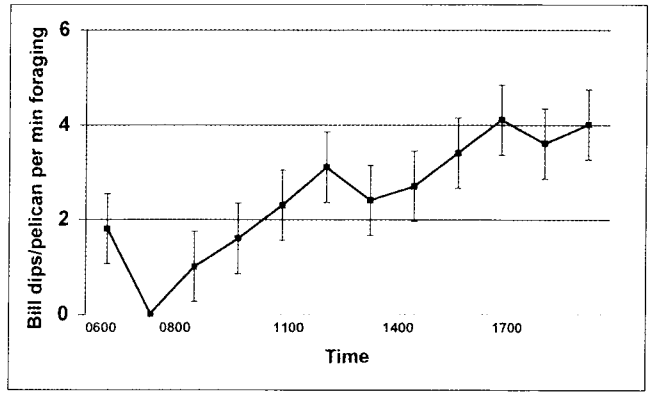

FIGURE 3. *Average (± SEM) dipping rate (N bill dips/ observed pelican/ min foraging) among diurnal observations of captive American white pelicans (N = 6) foraging on experimental channel catfish aquaculture ponds.*

Table 1. *Channel catfish consumption by American white pelicans foraging on experimental aquaculture ponds. Pelicans (N = 5) were present on treated pond halves during a 10-day foraging trial; pelicans were excluded from control pond halves. Fish consumption was calculated based upon the number of fish stocked in the treated half minus (fish harvested and observed mortality in treated half plus fish morality in control half).*

Pond	Treated pond fish stocked	Treated pond (Fish harvested + observed mortality)	Control pond (Fish stocked-harvested)	Fish consumption (No./10 d)	Fish mass (g)	Fish consumption (kg/10 d)	Energy intake[a] (kJ/10 d)
(Trial 1)							
1	1,500	1,245	29	226	39	8.8	52,884
2	1,235	1,124	4	107	40	4.3	25,680
3	1,500	1,176	100	224	39	8.7	52,416
(Trial 2)							
2	1,500	968	0	532	34	18.1	108,528
3	1,500	1,201	28	271	38	10.3	61,788
Average ± SEM						10.0 ± 2.3	60,259 ± 13,498

[a]*Energy intake was based upon 6.00 kJ/fresh g channel catfish (Brugger 1993).*

pond levees (86.6%), and 652 min loafing on test ponds (4.8%). The rate of bill dipping (Fig. 3) was greater from 1500–1800 h relative to 0700–0800 h ($F_{11,55} = 2.9$, $P = 0.005$). The efficiency of catfish captures did not, however, differ among diurnal hours ($P > 0.3$).

Discussion

These observations confirm that captive American white pelicans forage at night during winter. McMahon and Evans (1992) regarded nocturnal foraging as a prudent strategy when food requirements cannot readily be met during daylight hours. These authors hypothesized that nocturnal foraging may be necessary during the breeding season when energetic requirements are high and diurnal flights (up to 100 km from the colony to feeding areas) are common. Nocturnal foraging may be influenced by food availability and diurnal food consumption. Thus, the extent of nocturnal foraging under natural conditions may differ from that observed on experimental aquaculture ponds.

Captive pelicans consumed approximately 1.0 kg of catfish per bird per day during the 10-d foraging trial. In contrast, breeding pelicans were estimated to consume 1.8 kg of food per day at Pyramid Lake, Nevada, USA (Hall 1925). The diurnal rate of bill dipping ranged from 0–4 dips/min during the present study. The rate of bill dipping is, however, highly variable and increases with flock size to about six dips per minute for four or more foragers (Anderson 1991).

Whereas group size affects the foraging strategies and foraging efficiency of American white pelicans (Anderson 1991), the present observations were likely affected by studying single birds foraging on relatively small ponds. Moreover, fish consumption was suppressed from 50–80% within the pond half stocked with 1,235 fish relative to those stocked with 1,500 fingerlings. Thus, fish density within catfish aquaculture ponds may affect the foraging behavior and efficiency of pelicans on these ponds.

McMahon and Evans (1992) attributed relatively low capture rates among nocturnally foraging pelicans to their lower visual sensitivity at night. These authors also suggested that pelicans may exhibit non-visual "probing" and increased dipping during their nocturnal foraging. We observed the diel foraging behavior of pelicans on experimental aquaculture ponds, where Secchi disc transparency averaged 14 cm (range = 9–23 cm). Similarly, Anderson (1991) observed the water throughout the pelicans' feeding range to be quite turbid during the breeding season. Thus, pelicans are not likely obligated to visual strategies for diurnal or nocturnal foraging.

This study evaluated catfish consumption by captive American white pelicans while controlling for other fish mortality factors (e.g., disease, poor water quality). Relative to control pond halves,

pelicans reduced fish abundance by 9–35% during the 10-d trials. These results indicate that the cost-effectiveness of both diurnal and nocturnal protection of aquaculture ponds should be considered. Estimates of daily catfish consumption on commercial ponds are needed to further elucidate the economic impacts of American white pelicans at channel catfish aquaculture facilities.

Acknowledgments

B. Dorr, G. Ellis, P. Fioranelli, D. T. King, and B. S. Woodruff were instrumental in capturing pelicans. I also appreciate the dedicated assistance of P. Fioranelli and B. S. Woodruff during video analyses and daily animal care. I am especially grateful to the Mississippi catfish fingerling producer that provided fish for this study. I thank S. C. Barras, S. Jojola, D. T. King, M. E. Tobin, and K. C. Vercauteren for their thoughtful review of a previous draft of this manuscript.

Literature Cited

Anderson, J. G. T. 1987. Foraging behavior of American white pelicans (*Pelecanus erythrorhynchos*) in western Nevada. Unpublished Ph.D. dissertation. University of Rhode Island, Kingston, Rhode Island, USA.

Anderson, J. G. T. 1991. Foraging behavior of the American white pelican (*Pelecanus erythrorhynchos*) in western Nevada. Colonial Waterbirds 14:166–172.

Brugger, K. E. 1993. Digestibility of three fish species by double-crested cormorants. Condor 95:25–32.

Carlander, K. D. 1969. Handbook of freshwater fishery biology, volume 1. Iowa State University Press, Ames, Iowa, USA.

Evans, R. M., and F. L. Knopf. 1993. American white pelican (*Pelecanus erythrorhynchos*). Pages–*in* A. Poole and F. Gill, editors. The birds of North America, no. 57. Academy of Natural Sciences, Philadelphia, Pennsylvania, and American Ornithologists' Union, Washington, D.C., USA. pp. 1-24.

Glahn, J. F., and B. S. Dorr. 2002. Captive double-crested cormorant *Phalacrocorax auritus* predation on channel catfish *Ictalurus punctatus* fingerlings and its influence on single-batch cropping production. Journal of the World Aquaculture Society 33:85–93.

Hall, E. R. 1925. Pelicans versus fishes in Pyramid Lake. Condor 27:147–160.

King, D. T. 1997. American white pelicans: the latest avian problem for catfish producers. Proceedings of the Eastern Wildlife Damage Management Conference 7:31–35.

King, J. O. and D. T. King. 1994. Use of a long-distance night vision device for wildlife studies. Wildlife Society Bulletin 22:121–125.

King, D. T. and S. J. Werner. 2001. Daily activity budgets and population size of American white pelicans wintering in south Louisiana and the delta region of Mississippi. Waterbirds 24:250–254.

King, D. T., J. D. Paulson, D. J. LeBlanc, and K. Bruce. 1998. Two capture techniques for American white pelicans and great blue herons. Colonial Waterbirds 21:258–260.

Low, J. B., L. Kay, and D. I. Rasmussen. 1950. Recent observations on the White Pelican on Gunnison Island, Great Salt Lake, Utah. Auk 67:345–356.

McMahon, B. F. and R. M. Evans. 1992. Nocturnal foraging in the American white pelican. Condor 94:101–109.

O'Malley, J. B. E., and R. M. Evans. 1984. Activity of American white pelicans, *Pelecanus erythrorhynchos*, at a traditional foraging area in Manitoba. Canadian Field Naturalist 98:451–457.

Palmer, R. S. 1962. Handbook of North American Birds, volume 1. Yale University Press, New Haven, Connecticut, USA.

Schaller, G. B. 1964. Breeding behavior of the white pelican at Yellowstone Lake, Wyoming. Condor 66:3–23.